Electronic Supplementary Information

Investigation of titanium mesh as a cathode for the electro-Fenton process: consideration of the practical application in wastewater treatment

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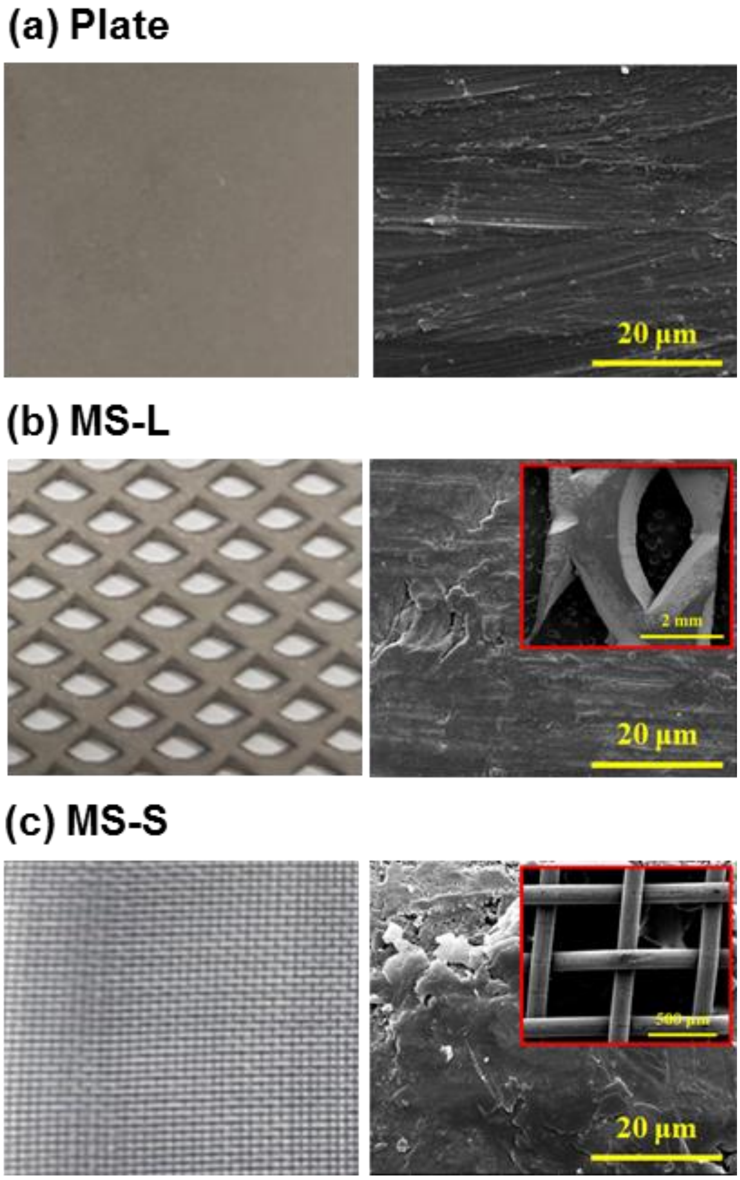

Fig. S1 Macro photographs and SEM images of commercial Ti electrodes with different morphologies: (a) plate, (b) mesh with large opening size (MS-L), and (c) mesh with small opening size (MS-S).

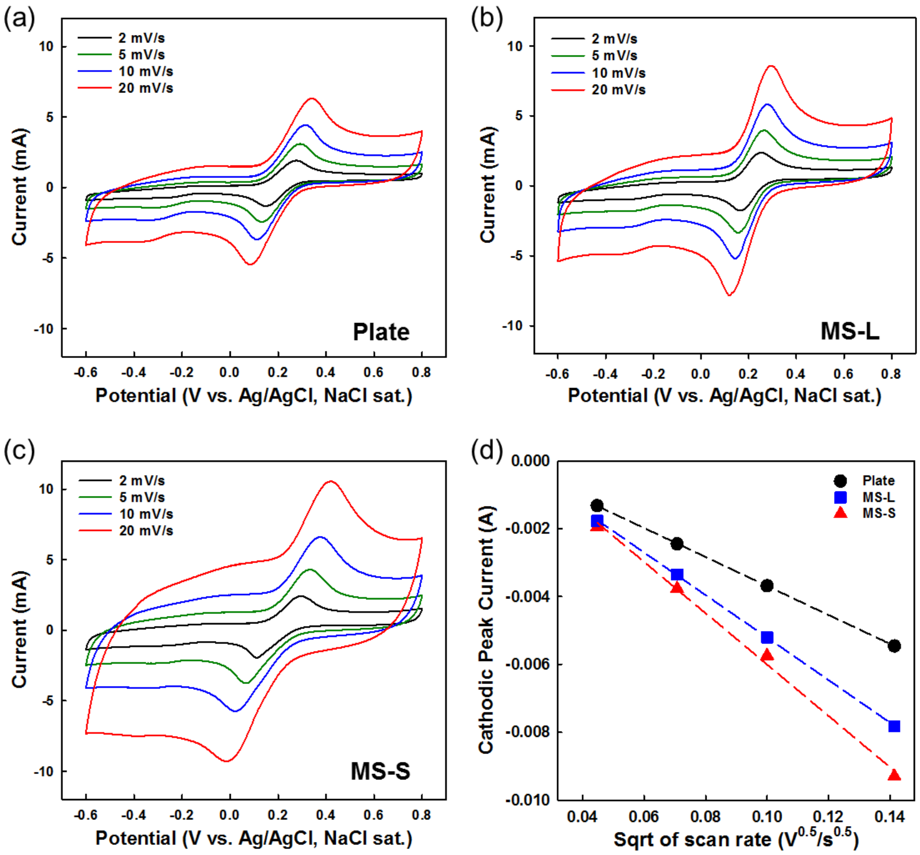

Fig. S2 Cyclic voltammogram of (a) plate, (b) MS-L, and (c) MS-S in 0.01 M $K_4Fe(CN)_6$ and 100 mM KCl supporting electrolyte. (d) Cathodic peak currents were plotted with respect to the square root of the scan rate. The absolute gradients of the cathodic peak currents and scan rates are 0.0428, 0.0628 and 0.0758 A $V^{-0.5}$ $s^{0.5}$, respectively, for plate, MS-L and MS-S electrodes.

Electrochemically active surface area (ECSA) is calculated based on the Randles-Sevcik equation as follows:

$$\mathrm{i_{peak}} = 0.4463 \times \sqrt{\frac{n^3F^3}{RT}} \times \sqrt{D} \times C_0 \times \mathrm{A} \times \sqrt{V_{rate}},$$

where n is the number of electrons involved in the reaction, D is the average diffusion coefficient of $K_4(FeCN)_6$ with a value of 6.56×10^{-6} cm^2/s,[1] C_0 is the initial concentration, V_{rate} is the scan rate, F is the Faraday constant, A is the geometric area of the electrode, R is gas constant, and T is the temperature.

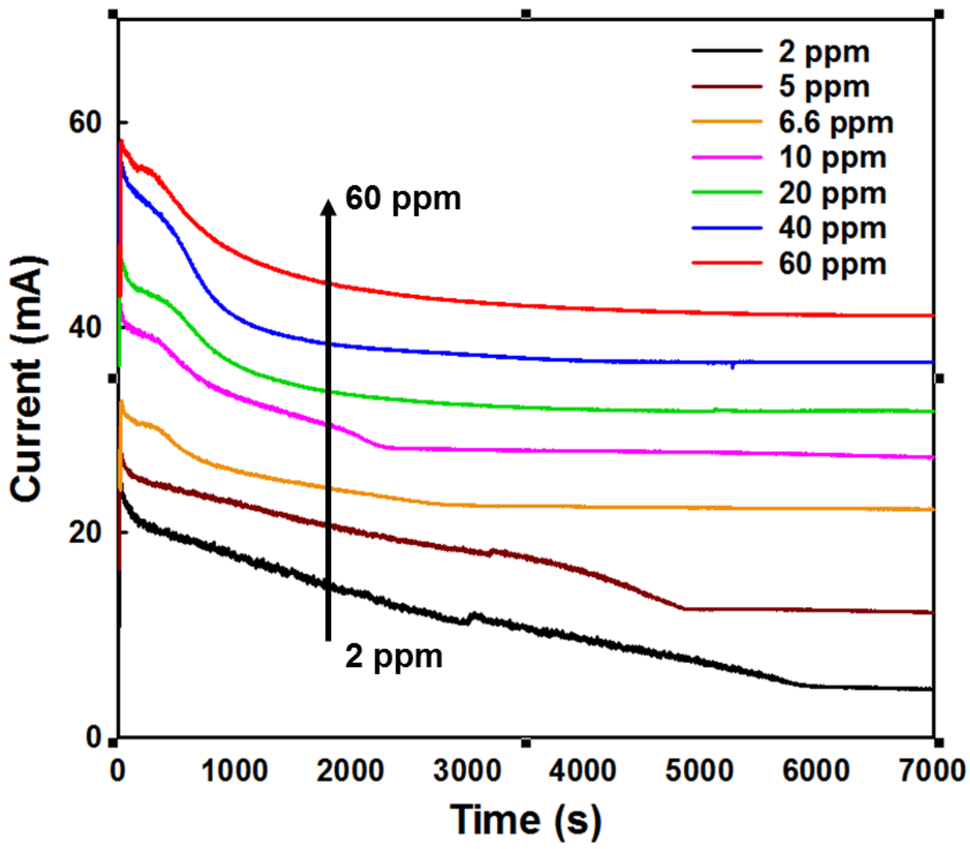

Fig. S3 Current profiles with respect to change in the Fe^{2+} concentration

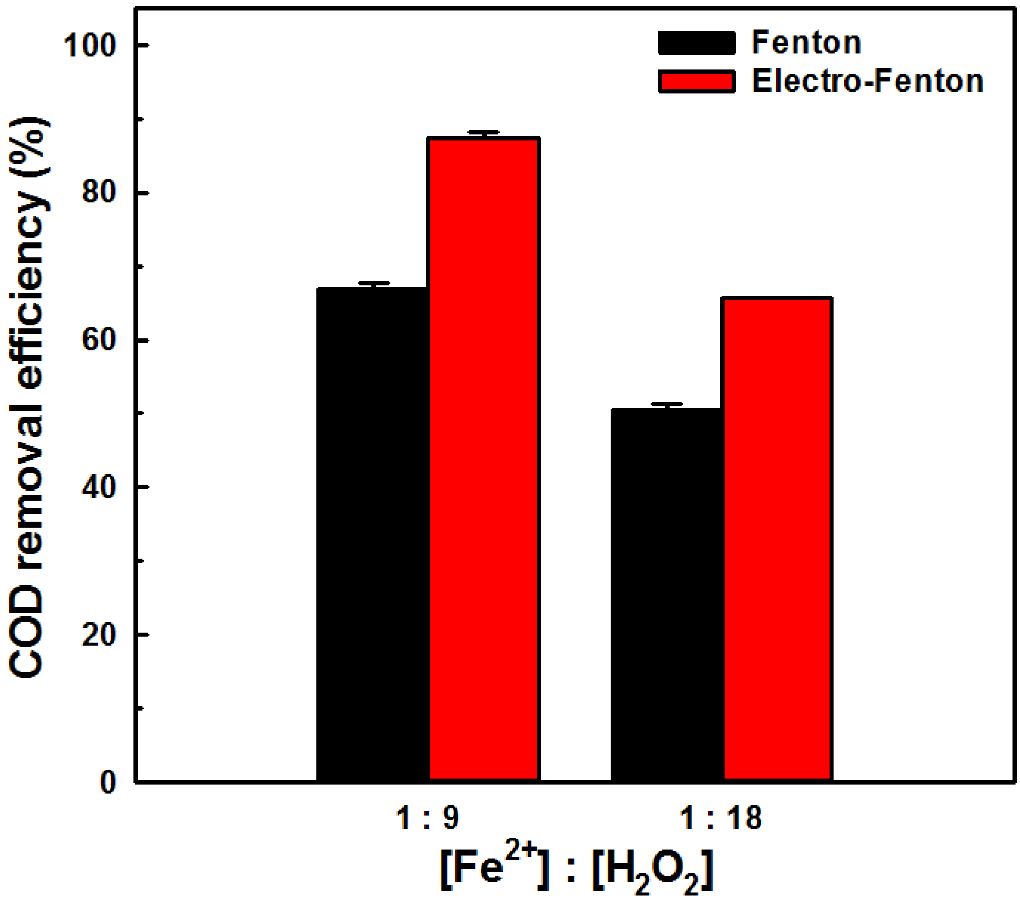

Fig. S4 Change in COD removal efficiency of the Fenton and electro-Fenton processes with respect to injected concentration ratio of Fe^{2+} and H_2O_2.

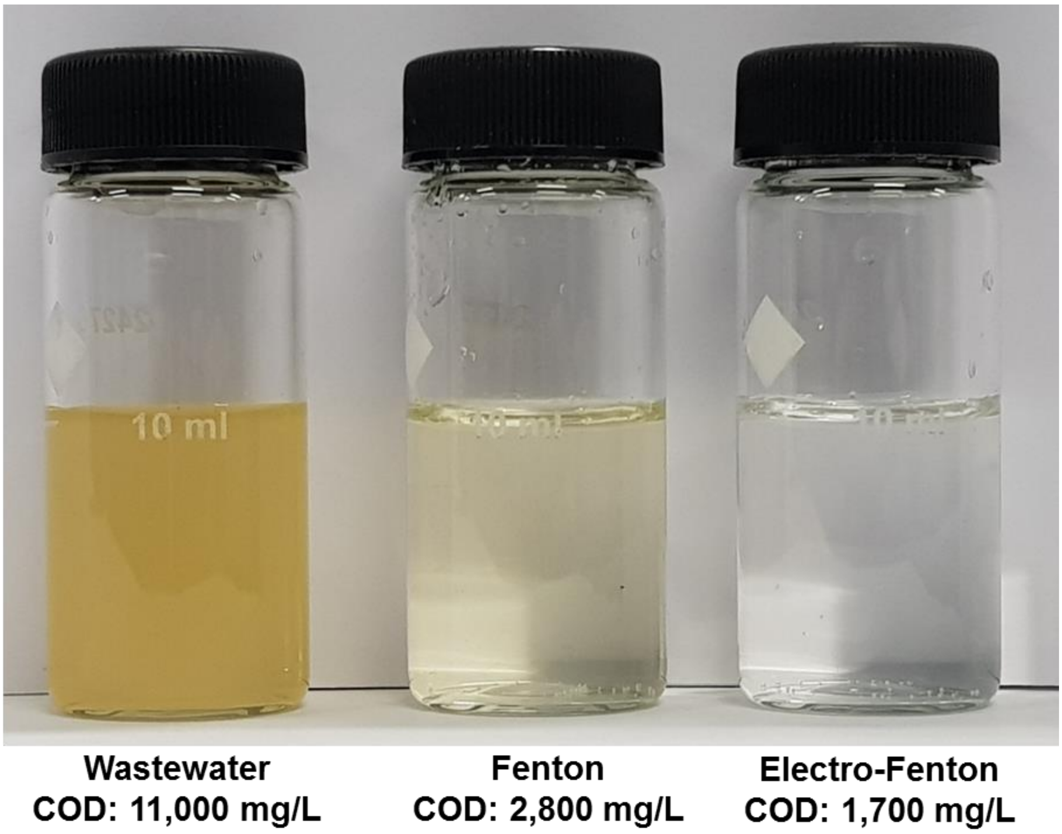

Fig. S5 Color and COD changes of real wastewater treated with the Fenton or electro-Fenton processes.

Table S1. Summary of operating conditions and energy consumption of electro-Fenton processes using different cathode materials.

Electro-Fenton system (cathode material)	Target compound	Operating conditions	Energy consumption	Reference
Titanium mesh electrode with large opening size	Real wastewater	Average cell voltage: 2.0 V	1.56 kWh/kg COD	This study
Carbon	Textile dye	Average cell voltage: 3.5 V	Not available	[2]
Stainless steel	Antimicrobials triclosan and triclocarban	Average cell voltage: 5.7 V	Not available	[3]
Graphite felt	methylene blue	Constant current: 50 mA (voltage not shown)	23 kWh/kg TOC	[4]
Nitrogen-doped graphene-carbon nanotube	dimethyl phthalate	Cathodic potential: -0.5 V vs. SCE	3.37 kWh/kg COD	[5]
Carbon (CMK-3) gas diffusion electrode	dimethyl phthalate	Cathodic potential: -0.5 V vs. SCE	538.9 kWh/kg COD	[6]
Graphite felt	Organic pollutants in RO concentrate	Cathodic potential: -0.72 V vs. SCE	60 kWh/kg COD	[7]
Graphite felt	Textile wastewater	Constant current: 300 mA (voltage not shown)	63.64 kWh/kg COD	[8]
Iron	Textile wastewater	Constant current: 200 mA (voltage not shown)	3.38 kWh/kg COD	[8]

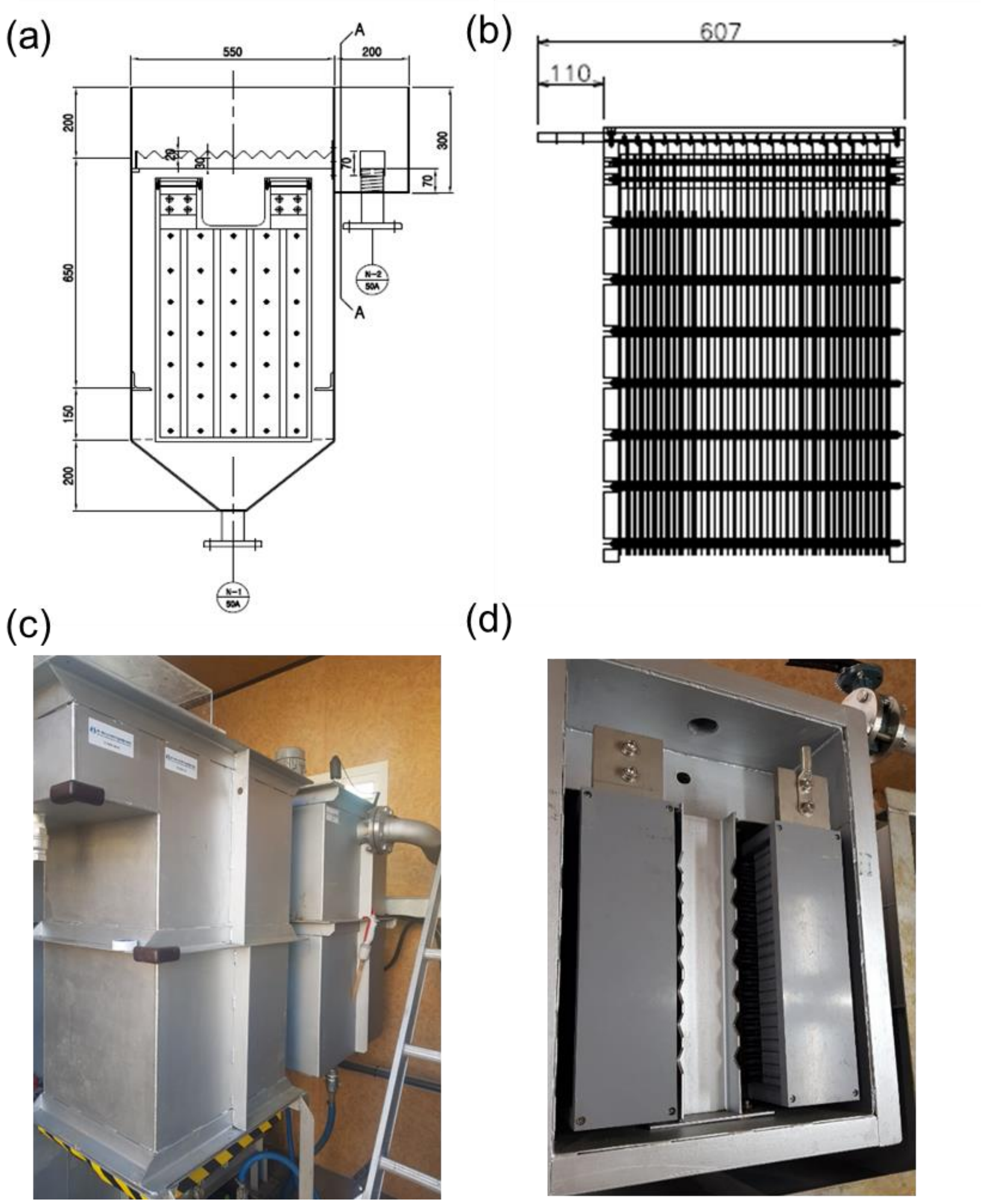

Fig. S6 Schematics and photographs of (a, c) pilot-scale electro-Fenton and corresponding (b, d) electrode stacks.

The electrode stacks were constructed by alternate stacking of twenty one titanium electrodes with large mesh size and twenty iridium oxide and ruthenium oxide coated titanium meshes as cathodes and anodes, respectively. The electrical cables were connected in parallel and ~ 2 V was applied to each pair of the electrodes.

Calculation of the cost in pilot scale electro-Fenton operation

Based on the representative result during the pilot experiment

(1) Amount of COD removed:

COD removed = Influent COD – Effluent COD → 1610 mg/L – 105 mg/L = 1505 mg/L

Volume of the reactor: 3130 L

Amount of COD removed: 1505 mg/L × 3130 L × 1 mg/10^6 kg = 4.71 kg COD removed

(2) Cost of Reagents (based on the purchased price)

253 mg/L Fe^{2+} and 159 mg/L H_2O_2 were injected.

Amount of $FeSO_4 \cdot 7H_2O$ injected:

$$\frac{0.253\text{ g Fe}}{\text{L}} \times \frac{\text{mol}}{55.945\text{ g Fe}} \times \frac{277.8\text{ g FeSO}_4\cdot 7\text{H}_2\text{O}}{\text{mol}} \times \frac{\text{kg}}{1000\text{ g}} \times 3130\text{ L} = 3.93\text{ kg FeSO}_4\cdot 7\text{H}_2\text{O}$$

Amount of H_2O_2 injected:

$$\frac{0.159\text{ g H}_2\text{O}_2}{\text{L}} \times \frac{\text{kg}}{1000\text{ g}} \times 3130\text{ L} = 0.49\text{ kg H}_2\text{O}_2$$

$FeSO_4 \cdot 7H_2O$ cost: 2.58 \$/kg × 3.93 kg $FeSO_4 \cdot 7H_2O$ injected = 10.1 \$

H_2O_2 cost: 3.18 \$/kg × 0.49 kg H_2O_2 injected = 1.56 \$

(3) Electricity cost (based on the unit provided by the Korea Electric Power Corporation)

Energy consumption: voltage × current × time → 2 V × 13 A × 3 h = 78 Wh = 0.078 kWh

→ 0.07 \$/kWh × 0.078 kWh = 0.005 \$

(4) Total cost:

$FeSO_4 \cdot 7H_2O$ cost + H_2O_2 cost + electricity cost = total cost

10.1 + 0.54 + 0.005 = 10.645 \$

Total cost per kg COD removed: 10.645 \$ / 4.71 kg COD = **2.48 \$/kg COD**

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